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Factsheet

SOIL COMPACTION

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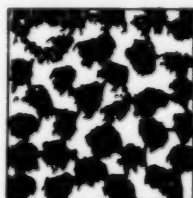
SCOPE OF THE PROBLEM

The compaction of agricultural soils is a serious problem and growing concern in the agricultural community due to its potential to seriously reduce the productive capacity of crop land. In areas of the world where intensive, "mechanized" agriculture is practiced, soil compaction ranks highly with other forms of land degradation (e.g. soil erosion and salinization) as a major threat to sustaining current agricultural production levels. In Southwestern Ontario, surveys have indicated that up to 42% of farmers have observed the effects of soil compaction on their farms. In municipalities where clay soils are predominant, the effects of soil compaction are generally observed more frequently than water erosion. Best estimates of the annual cost of soil compaction and erosion to Ontario farmers, place each in the \$70 MILLION range.

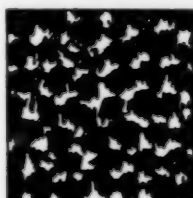
WHAT IS SOIL COMPACTION?

Soil compaction is the process of increasing the density of soil by packing the particles closer together causing a reduction in the volume of air. The volume of water, at least initially, remains unchanged. Soil water acts as a lubricant increasing compaction when a load is imposed on the soil. If near saturation, however, the load is likely to exceed the soil strength and bearing capacity, resulting in excessive wheel slippage and rutting as well as soil mixing and smearing.

Ideally, about 50% of the total soil volume should be pore space filled with equal volumes of air and water (see Figure 1). By packing primary soil particles (sand, silt, clay) and soil aggregates closer together, the balance between solids, air-filled and water-filled pore spaces are dramatically altered.



Uncompacted

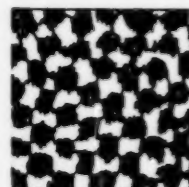


Compacted

Figure 1. The effect of compaction on pore space

Compaction usually eliminates the largest soil pores first. A large portion of the initial soil air is forced out of the upper plant root zone, and the channels of greatest continuity, and least resistance to air movement, water movement and root penetration are destroyed.

Under comparable conditions, soils with a range of soil particle sizes (ie. fine sandy loam) are generally more compactible than soils of uniform particle size (ie. sand). The finer soil particles easily fill the large pores formed by the coarse particle fraction in a poorly sorted soil, producing a denser soil (see Figure 2).



Well sorted



Poorly sorted

Figure 2. The effect of soil texture on compactibility.

WHAT ARE THE CAUSES OF SOIL COMPACTION?

Compaction of soil is typically divided into two types:

1. Tillage-induced

Tillage-induced compaction is caused by primary tillage under less than optimum soil moisture conditions and by excessive secondary tillage. This form is most apparent in the soil's plow layer (Ap horizon). Secondary tillage destroys soil aggregation and structure allowing the surface soil to puddle, crust, and reach densities greater than would otherwise occur in an untilled state. Furthermore, many of today's larger tillage implements (ie. discs) can exert tremendous stresses and pressures on the soil at the base of the plow layer. This frequently leads to the formation of a horizontal compaction zone or plowpan at a depth of 10-20 cm. With moldboard plowing under wet conditions, the base of the moldboard can cause smearing and localized impermeable layers. The major compaction

problem, however, is associated with the rear wheel of the tractor running in the open furrow, forming a compacted layer at even greater depths (ie. up to 30 cm or greater).

2. Traffic-induced

Traffic-induced compaction is caused primarily by wheel traffic associated with farm operations and is of greatest concern in the subsoil zones. Compaction below the plow layer is generally of more concern since it is not easily self-correcting (ie. freezing-thawing, wetting-drying cycles) and is difficult if not impossible to totally reverse or correct. Of lesser but significant importance is traffic stemming from the movement of construction-class and maintenance vehicles along utility (ie. hydro, pipeline) right-of-ways where they cross agricultural land.

It has been estimated that, given conventional tillage practices and other planting-harvesting farm operations, as much as 90% of the field area will be wheel tracked on an annual basis and that much of the field area receives 4 or 5 wheel passes. These acts, when combined with the considerable gross vehicle weights of larger farm vehicles (often 10 to 20 tonnes or more), demonstrate the magnitude of wheel loadings currently being imposed on Ontario soils.

The concern about using heavy vehicles on wet soils originates from field experimentation which has shown that, at a given tire contact pressure, changes in soil porosity and density extend deeper into the subsoil with increasing vehicle axle loads (see Figure 3) and with increasing soil moisture content. Such effects have been measured at depths of 50 cm and greater with axle loads of about 10 tonnes.

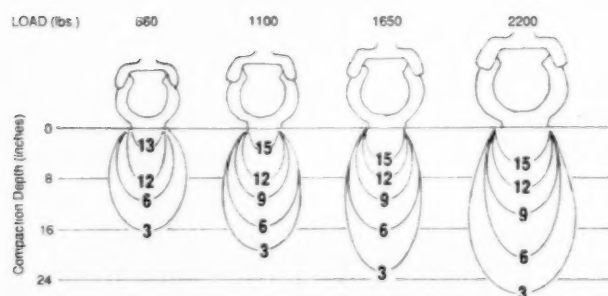


Figure 3. The effects of axle load on the depth of soil compaction.

HOW TO DIAGNOSE A COMPACTION PROBLEM

Figure 4 depicts the major soil and crop symptoms which are useful in identifying the nature, degree and extent of the problem in the field. There is no rapid or simple means of measuring compaction damage in the field.

Three methods to indicate field compaction are;

1. **Shovel or Probe** This method measures compaction by the resistance encountered as you push down through the soil. It is useful for detecting dense soil layers that may resist root penetration or growth.
2. **Penetrometer** This instrument provides relative measures of soil strength and resistance to root penetration, but the measures are highly sensitive to soil moisture content. These readings still require adjustment and careful interpretation before they can have any great practical meaning.
3. **Soil Pit Dig** a small pit crossing the crop root zone, use a knife to examine the rooting pattern and test the resistance to penetration. Note denser zones of soil and see if they coincide with a reduction in root growth.

All three methods are relative tests, and should be compared to areas with similar soils and where compaction is known not to be a problem.

These methods are of assistance in finding dense layers in areas where soil and crop symptoms (Figure 4) have been observed.

PREVENTION OF SOIL COMPACTION

Since compaction problems are likely to persist for a prolonged period of time, the best defence is avoiding the problem altogether.

1. Schedule farm operations to avoid working fields when wet – the soil should break easily and crumble at the deepest depth as it is being tilled.
2. Reduce secondary tillage passes – each additional tillage pass destroys aggregates and increases bulk density.
3. Remove excess weight – use only enough ballast to reduce slippage.
4. Reduce surface pressure – can be accomplished by reducing tire pressure or by using lighter axle loads.
5. Improve drainage – reduces risk of being forced to work wet fields.
6. Traction versus compaction long narrow footprint is preferable to a short wide track (ie. duals). This can be accomplished by the following:
 - (a). using larger diameter tires
 - (b). replacing bias tires with radials
 - (c). tandem axles
 - (d). front wheel assist, 4 wheel drive
 - (e). track vehicle

Note Duals don't eliminate the potential for sub-soil compaction.

7. Control traffic patterns (ridge till, tramlines) – under conventional tillage systems as much as 90% of the land area is tracked at least once.

8. **Reduce axle loads**-Potential for subsoil compaction increases dramatically with axle loads of greater than 5 tons.
9. **Crop rotation** A good rotation is essential to stabilize and build soil aggregates – rotation crops should include both deep rooted and fibrous rooted crops.

CORRECTION OF SOIL COMPACTION

1. **Annual Variation in Tillage Depth** This is a method of dealing with tillage induced compaction layers occurring just below the normal working depth of the primary tillage implement. The tillage depth is decreased in a wet year and is increased in a year when soil is dry enough to shatter a compactive layer.
2. **Crop Rotation** This is normally a long term method of reducing compaction. Rotation should include deep rooting crops such as alfalfa, sweet clover and winter canola.
3. **Subsoiling** This should be attempted only when soil is dry and crumbles at the depth you are tilling. Operating depth should be no more than a few centimeters below the zone of compaction because any deeper uses more energy and risks the potential of deeper compaction. Usually the most suitable time would be the month of August. After sub-soiling, preventive measures should be implemented to avoid a recurrence of the problem.

COMPENSATION FOR SOIL COMPACTION

1. **Nutrients** Increased rates of fertilizer, do not fully compensate for restricted root growth of crops grown on compacted soils. Caution must be taken when adjusting fertilizer rates to offset the effects of soil compaction. Excessive rates may cause burning of the seed as it germinates and roots.
2. **Weather** Variations in annual weather conditions can change the severity of the effects of soil compaction on crop growth and yield. A yield reduction may be noticed in a particularly droughty year.
3. **Crop Selection** Plan to grow crops which are less susceptible to soil compaction such as forages. Row crops are comparatively vulnerable to soil structural problems.

GLOSSARY

pore space – the spaces between the solid soil particles

bulk density – the weight of soil per unit volume

axle loads – the weight on each axle

tire contact pressure – equivalent to inflated air pressure in the tire

Types of Compaction	Soil Symptoms	Crop Symptoms
<u>Traffic Induced</u>		
- Deterioration of surface soil aggregates	- ponding of surface water	- delayed or reduced seedling emergence
- Decrease in porosity	- formation of soil crusts	- uneven crop stands
- Pan formation	- lower soil temperature	- nutrient (N) deficiencies
	- increased runoff	- plant water stress
	- reduced soil water storage	
<u>Tillage Induced</u>		
	- increased implement draft and fuel costs	- shallow root system
	- increases resistance to root penetration	- drought stress
- Decrease in soil porosity	- poor soil aeration	- nutrient deficiencies
	- poor soil drainage	- unhealthy roots
		- reduced crop growth-yield
		- delayed crop maturity
		- plant water stress

Figure 4. Soil and crop symptoms of tillage and traffic-induced compaction.

